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ELECTRIC-SPARK METALWORKING IN THE USSR

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[Figures referred to are appended.]

For many decades, leading laboratories have conducted and are still conducting research to prevent deterioration of electrical contacts during circuit-switching.

The Soviet scientists N. I. and B. R. Lazarenko, who were awarded the Stalin Prize in 1946, have also been studying this problem since 1935. Having determined the causes of erosion, the Lazarenkos and their associates learned how to effect a partial control of this phenomenon. In 1943, the Lazarenkos suggested the use of erosion for metalworking.

Since 1945, the Soviet Union has pioneered the use of electrical erosion for the working of very hard metals on an industrial scale. At present, the electric-spark method of metalworking is used in many technological processes, particularly in the manufacture of hard-alloy tools.

State organizations are following carefully the development of this new method of metalworking and aiding its introduction into industry in every way possible. Specialists in the electric-spark method of metalworking are being trained at technical schools.

The Nature of the Electric-Spark Process

In the opening or closing knife switches, cut-outs, etc., growths or crater-shaped recesses with an ulcerated surface frequently appear on the ends of the switch knives and other contact surfaces. This deterioration of the contact

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components is due to the buildup and decline of the electrical charges during the opening or closing of the electric circuit. Such deterioration of the electrodes is known as electrical erosion. Metallic rusting, which is of an electrochemical nature and is caused by the action of oxygen, also leads to deterioration. This electrochemical deterioration is known as corrosion.

Up to the present, electrical erosion was considered, and in many instances is still considered, a harmful phenomenon. However, as noted above, research by Soviet scientists (the Lazarenkos) indicated that not only could this harmful phenomenon be curbed, but that it could be of value in the search for new processes of metalworking.

In seeking a means to curb electrical erosion, the first step was to examine the causes. After these were determined, it was possible to discover effective means of control. What, then, are the causes of electrical erosion and how can they be controlled?

Let us study what happens when we open and close a direct-current circuit. Figure 1 (sketches a, b, c, d, e) shows various conditions in an electric circuit; a shows a closed circuit; b, a circuit that is beginning to open; c, an open circuit; d, a circuit that is beginning to close; and e, an almost closed circuit.

In Sketch a, forces P_1 and P_2 tend to disconnect the electrodes A and K. Simultaneously with the opening of the circuit (Sketch b) we can observe the luminary and the thermal effects of the arc discharge, which is characterized by a high temperature (2,600-4,000 degrees centigrade), a predominant transfer of cathode-material K to the anode A, and a relatively lengthly process of particle transfer (the duration of the arc discharge is from 0.1 to 0.0001 seconds), with the transferred metallic particles giving the appearance of being spread over the surface; this contributes to the externally rough appearance of the surfaces of the electrodes A and K.

In Sketch c, an open circuit is shown, where the arc discharge has become extinguished as a result of increasing the anode-cathode (A-K) gap. A capacitor is connected parallel to the electrodes A and K. In this case, with a given capacitance, the arc might not reappear. The capacitor is made up of condensers which, when charged, store electric power. With an almost open circuit, as shown in Sketch d, no discharge takes place, because the distance between A and K is still great. However, if the anode-cathode gap is decreased to about 0.05 millimeter (if the source voltage is 220 volts and the capacitance is 300-400 microfarads), then an electric discharge takes place. This discharge, to distinguish it from the arc discharge, is called the spark discharge. The spark discharge is characterized by a high temperature (10,000 degrees centigrade) which occurs instantaneously and does not penetrate to the inner layers of the metal; and by a predominant transfer of metal particles from anode to cathode. A direct transfer of metal particles takes place only at the surface where the spark discharge occurred.

Comparison of the characteristics of the arc and spark discharges shows that both discharges can be utilized for metalworking purposes, the former for rough metalworking such as welding, cutting, etc., the latter for more precise, profile-shaping work.

Sketch e shows the arrangement for the electric-spark working of metals suggested by the Lazarenkos. Circuit No 1 is called the feed circuit, while circuit No 2, in view of the periodic nature of its functioning (the capacitor becomes charged when the circuit is disconnected and charged through the spark gap when the circuit is closed), is labeled the discharge circuit and constitutes the basic work circuit.

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The intensity and duration of the spark discharge is easily controlled by varying: (1) the capacitance C by switching of condensers; (2) the current by varying the resistance R (which is connected in series with the feed circuit); (3) the voltage of the feed source (measured by the voltmeter V); (4) the material composition of the electrodes A and K; and (5) the nature and the state of working (dielectric) media of the spark gap μ .

The importance and the influence of each of these factors can be described as follows:

1. The capacitor C, which is connected in parallel with the feed circuit (No 1), serves to store up power and to effect its subsequent release in the form of a strong spark discharge.

The power generated during the discharge does work in connection with the heating of the electrode surfaces to a shallow depth, as well as in connection with the ejection of the electrode particles into the spark gap μ . The electric capacitor facilitates the formation of the spark discharge. By increasing or decreasing the capacitance as well as other parameters, it is possible to regulate the electric-spark process and make the discharge reversible, changing arc discharge into spark discharge and vice versa. A small capacitance or no capacitance at a high current leads to the arc discharge. By increasing the capacitance under proper conditions, a transformation of the arc discharge into the spark form is possible.

The value of the capacitance has a bearing on the surface finish of parts worked by this method. By decreasing the capacitance, higher quality surfaces can be obtained. In practice, the values of capacitance employed in electric-spark units vary between 0.25 to 600 microfarads.

2. The ballast resistor R, which is in series with the feed circuit, serves to regulate the charging current so as to obtain a certain ratio between the capacitance and the current in order to insure the occurrence of the spark discharge. In addition, the current has a certain effect on the productivity of the process, as well as upon the quality of the surface finish of the final product. The greater the current, the higher the productivity of the electric-spark process, with poorer quality of the surface finish of the final product; and conversely, a lower current decreases the productivity of the process but results in better finished surfaces of the manufactured product. In actual practice, the following current values are used in existing electric-spark units: 0.2 to 30 amperes for aperture making; 0.2 to 7 amperes for surface hardening, engraving, and plating; and 0.2 to 300 amperes for grinding, tool grinding, finishing, and cutting purposes.

3. The form of the discharge is also dependent on the voltage (which is measured by a voltmeter connected in parallel with the spark gap). With supply voltages of approximately 10 volts, it is possible to operate in the spark region at any current strength without connecting any capacitance since an arc discharge does not usually take place under these conditions. The range between 7-15 volts represents the "minimum arc striking potential," and, with a higher voltage, favorable conditions for arc formation are created. To produce the spark discharge at high voltages, it is necessary, as has been stated previously, either to connect the capacitor or vary the other parameters such as the composition of the workpiece electrodes, nature of the dielectric medium, etc.

Depending on the functions of existing electric-spark units, the following supply voltages are used: 80-220 volts for aperture making; 40-160 volts for surface hardening, engraving, and plating; and 10-70 volts for grinding, tool grinding, finishing, and cutting purposes.

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The magnitude of voltage also affects the productivity of the process, as well as the surface finish of the part worked. For instance, in tool grinding, grinding, and finishing, lowering the voltage will improve the surface quality of the finished product. Under these conditions, the spark gap decreases; however, the productivity of the unit is not lowered, owing to the increase in spark frequency. It may be noted that in all instances, the increase in voltage is accompanied by a corresponding increase of the spark gap.

4. Various materials are used for the electrode tool and the electrode workpiece in the electric-spark process.

The electrode tool is connected to the negative side of the direct current supply. It serves as the cathode in all operations of the electric-spark process except in plating, hardening, and sometimes, engraving. The piece to be worked on, which is connected to the positive terminal of the direct-current supply, can be of any current-conducting material, e.g., any steel, alloy, metalloceramic, etc. In all of these instances, the workpiece is the positive electrode (anode).

In practice, the following materials are used for the cathode tool: copper, cast iron, brass, cuprographite composition (the cuprographite composition is composed of a pressed copper and graphite powder with an occasional admixture of lead; the cuprographite composition is used for electric-motor brushes), etc., for aperture making; cast iron, steel, iron, cuprographite composition, etc., for tool grinding, finishing, grinding, and cutting.

By suitable selection of the electrode material, it is possible to regulate the extent and the type (znak) of electrical erosion which, in turn, affects the productivity of the electric-spark process, as well as the surface finish of the final product. The choice of the electrode-workpiece material is usually limited by the technology of production. In regard to the electrode tool, a suitable choice must be made to achieve minimum tool wear, high surface quality of the finished product, and high productivity of the process.

5. The dielectric working medium prevents the transformation of the interelectrode spark into an arc and facilitates removal of waste products from the discharge zone.

Not only dielectrics (nonconductors) but also such semiconducting media as waterglass, kaolin, various salts, etc., can be used for the working medium. These media are capable of extinguishing the arc and sustaining the spark discharge, whereas the electrical parameters sometimes favor the arc discharge; that is, they can raise the voltage on which the minimum arc striking potential depends. The chemical effect of the semiconducting media should also be noted, since, in some cases, it contributes to the destruction of the surface layer of the electrode workpiece. Some working dielectric media, under certain conditions, have an effect on the chemical structure of the surface of the material being processed. For example, kerosene can "carbonize" the surface of the electrode workpiece, whereas atmospheric nitrogen is capable of "nitrating" the working surface of the electrode to a small depth, thus hardening the surface of the workpiece.

In practice, the following dielectric and semiconducting media are used in the electric-spark process: kerosene, oil, etc., for aperture making; oil, kaolin suspension, salt solutions, compressed air, waterglass, etc., for grinding, tool grinding, and finishing; kaolin suspension, waterglass, etc., for cutting; and air for hardening, plating, and engraving.

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The working medium has an effect on the productivity of the electric-spark process, as well as upon the quality and the surface structure of the finished product.

In operations having to d with grinding, tool grinding, finishing, and cutting, the electric-spark pr ess is affected considerably by the revolving speed of the cathode tool. The optimum (experimentally determined) speed of revolution of the cathode tool, which results in maximum productivity and good surface finish, is 12-16 meters per second. A greater speed (25-30 meters per second) results in a better surface, but it lowers productivity. A very low speed of 3-5 meter per second results in both a lower productivity and a poorer finish. Observations show that, in some instances, by increasing the revolving speed of the cathode tool to 25-30 meters per second, the arc discharge can be transformed into the spark form.

Thus, it is seen that the following factors affect the producti, surface finish, and the structural surface variations during the electric-spark process: the capacitance, current strength, voltage, electrode composition, nature of working medium, and speed of the electrode rotation in operations involving grinding, tool grinding, finishing, and cutting.

On the basis of a large volume of experimental data, it is possible to conclude that the productivity of the electric-spark process depends on the quantity of electric power expended in the spark gap during the discharge, while the amount of electric power is directly proportional to the current intensity in the work circuit. It is not difficult to understand that the current in the work circuit is greater than that of the supply current.

In Sketch e of Figure 1, two ammeters are shown: A_n, which is in series with the feed circuit; and A_p, which is in series with the discharge circuit. By reading these ammeters, it is possible to judge the part played by each circuit in the process. When A_n indicates units of amperes, A_n reads tens of amperes; when A_n shows tens of amperes, A_p readings are in hundreds of amperes, etc. From this, the great importance of the work of the discharge circuit can be seen readily. As previously noted, the duration of the spark discharge is extremely short, i.e., 0.0001 to 0.00001 second. Therefore, despite the great temperature of the spark, about 10,000 degrees centigrade, this temperature does not penetrate throughout the workpiece and the electrode tool. Only a fine layer of 0.02 to 0.1 millimeter is subjected to erosion.

Since the spark discharges proceed in a strictly directional manner, the shape of the electrode tool (cathode) is duplicated precisely, depending on the working conditions, at the anode, thus insuring production within required tolerances.

Applications of the Electric-Spark Metalworking Process

The electric-spark metalworking process is constantly enjoying a wider acceptance by the metalworking industry. Of all the various forms of the electric-spark process, the following four are most important and necessary: (1) aperture making; (2) surface plating and hardening; (3) grinding and finishing of cutting tools; and (4) cutting.

1. Aperture-making Equipment

Production of electric-spark units on a large-series scale does not yet exist. Each plant adopting this process solves its own problems. Generally speaking, the electrical arrangement corresponds to that shown in Sketch e of

Figure 1. Conventional drilling or vertical milling machines comprise the basic unit; special frames and columns similar to those for drilling and milling machines are used in some cases. Two examples of modifying and adapting drilling and vertical milling machines for the electric-spark method of aperture making are described below:

Figure 2 shows a vertical drilling machine with hand feed converted to an electric-spark unit. The table of the cast iron frame (1) has T-shaped milled grooves to hold the workpiece. A bottomless tank (6) is mounted on the table with a grommet or a rubber or plastic gasket. The table of the frame (1) serves as the bottom of the tank. Consequently, the positive terminal of the direct current is connected to table and the workpiece. The hollow spindle (2) contains a coaxial textolite or hard-rubber insulating bushing (3) which separates the frame from the electrode tool. A three-jaw self-centering chuck (5) which serves to hold the electrode tool (4) is fitted on the tapered surface of the bushing. This chuck (5), i.e., the electrode tool, is connected to the negative terminal of the direct current. The machine spindle (2), together with the electrode tool, in this particular case has a hand feed; Coarse feed is by means of a lever or hand wheel, and fine feed by means of a screw located at the upper part of the machine. These feeds move the spindle forward only, without rotation.

The tank (6), in which the work is placed, is filled with kerosene, oil, or other working medium, so that its level is from 80 to 100 millimeters above the upper surface of the work. The working media drains through a pipe with stopcock.

A control panel placed alongside the machine. The bottom part of this control panel contains the condenser bank which is connected in parallel with both the tool and workpiece electrodes. A thermal ammeter is connected to the discharge circuit. A ballast resistor, in the form of a slide-type rheostat, is located to the side of the control panel. This rheostat, like the ammeter, is connected in series with the feed circuit. The capacitance is varied by means of switche Gases liberated by the working medium are drawn off by a ventilating exh st pipe.

This installation can be converted easily from hand feed of the electrode tool to automatic feed. At present, there are several types of heads with automatic feeds. These include mechanical, solenoidal, electrodynamic, and the latest design of a "rigid drive" automatic head with countermagnetic fields, designed by Ye. M. Levinson and Ye. A. I. Vladimirov. This modification consists of installing one of the above units instead of a spindle on the slide of the vertical-column way.

A vertical milling machine can also be modified for aperature making by the electric-spark process. This modification is similar to that of the drilling machine and consists in using a bushing to insulate the electrode tool from the column. The table of the machine has three planes of free movement; one in a vertical direction, and two on a horizontal plane (lengthwise and crosswise). Moreover, the spindle head can be swiveled at an angle of 20-30 degrees to the plane of the table. All this broadens the productive versatility of the unit. The size of the tank permits processing of parts up to 150 x 200 x 500 millimeters in size, e.g., forging die blocks. The feed can be manual by raising the table or automatic by using a head mounted on the upper part of the machine, designed by Ye. I. Sametskiy.

The following table contains the electrical and other parameters which are necessary to maintain the proper working conditions:

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Elec and Other Parameters	Rough (Preliminary)	Medium (Semi-finished)	Fine (Intermediate	Fine (Finish)	[Final] Finishing
Voltage	160-220	120-160	100-140	Up to 100	Up to 80
Capacitance (mfd)	400-600	150-300	60-150	10-20	Up to 2
Short-circuit current (amp)	25-40	10-25	5-10	1-5	Up to 1
Working medium	Kerosene	Kerosene, oil	Oil, kerosene	Oil, kerosene	Oil, kerosene

The order of procedure on the electric-spark units is as follows: the work is fastened to the table or in a fixture, and the tank is filled with the working medium. Then the necessary working conditions are determined; a capacitance of 600 microfarads, for example, is selected by switches; the electrode tool and the work circuit are then short-circuited; and by means of the rheostat the short-circuit current is set at, for example, 40 amperes. The electrode tool and the work are drawn apart, then gradually brought together until a spark is formed.

The ammeter reading should be 60-80 percent of the short-circuit current; in this example, the ammeter should read 24-32 amperes.

The aperture is considered finished when the electrode tool can move freely through it. With automatic feed, the spark gap is kept constant automatically until the aparture is made; after it is made, the feed is disconnected.

The electric-spark process permits obtaining precise holes in hard-alloy dies. Previously, precise and complex profiles in hard-alloy dies could not be obtained successfully. This method is also used for the production of alloy-steel cutting dies.

According to former practice, apertures in diesel-engine spray nozzles were drilled in untreated metal. The expenditure of drill bits was enormous since they often broke on the spherical surface. Moreover, many nozzles had to be scrapped because the burrs inside the nozzle, which remained after drilling, frequently fused and filled the apertures during subsequent heat-treatment. At present, the technology of this process has been changed. The nozzle is completely finished, and the apertures are then produced by the electric-spark process. The time taken for each aperture is about 20 to 30 seconds. There is no waste and no need for the subsequent use of drills and high-speed drilling machines.

Various shapes of electrode tools made of different material are used. Among these are copper graphite and brass (Type LS-59) punches. Their shapes and sizes are dictated by the size of the work, with corresponding allowances for electrical and mechanical wear. Experimentally determined allowances are made for the plane surfaces, no theoretical determination of allowances as yet being possible.

The manufacture of apertures, depending on the accuracy required, can be conducted by observing the following electrical parameters:

	Allowance for Aperture Making (mm)	Current (amp)	Capacitance (mfd)	Voltage	Working Medium
1	0.02	0.1	5	60	Kerosene
2	0.02-0.05	0.8	20	80	Kerosene
3	0.10-0.20	10.0	100	120	Kerosene
4	0.4	15.0	400	170-220	Kerosene

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By utilizing the electric-spark method of producing holes in heat-treated parts, it is possible to conduct many auxiliary maintenance tasks. For example, in the production of crankcases for internal combustion engines, the final operation consists of drilling base-plate holes and threading them. Frequently, a screw tap breaks during tapping and becomes lodged in the opening. Until recently, the broken tap could not be extracted and the entire crankcase had to be recast. By the electric-spark process, a hole is made in the center of the broken screw tap, thus facilitating, its removal with the resultant saving of the crankcase. Many Soviet plants are now equipped with such electric-spark units.

2. Plating and Surface Hardening

The principal electrical arrangement for the plating and surface hardening of various metals is the same as that shown in Sketch e, Figure 1. It differs from the aperture-making arrangement in that the positive terminal of the supply current is connected to the electrode tool, i.e., the material which is to be deposited on the workpiece; whereas, the work is connected to the negative terminal. Furthermore, in aperture making, the electrode tool moves forward only, whereas in plating or in surface hardening, the electrode tool has a reciprocating movement.

All this is shown in Figure 5 [Figures 3 and 4 are not reproduced but are available in original in CIA], where the positive terminal of the direct current is connected to the vibrator holder, to which, in this case, a hard alloy plate is secured. The negative terminal of the working circuit is connected to the brass plate of the table on which the object to be electroplated or hardened is mounted. In this case, the object is a gear rack. Alongside the table a ballast resistor in the form of two sliding-type rheostats which are in series with the supply circuit is installed. Condensers in parallel with the electrodes, forming the oscillatory discharge circuit, are located at the bottom part of the table. A control panel with a voltmeter, an ammeter, and condenser switches are at the operator's eye level. Figure 5 shows the general appearance of the vibrator used for plating and hardening. The vibrator, or "gun," is used widely for pneumatic paint spraying, unscrewing, etc. In this case, an obsolete gun containing a coil fed by an alternating-current lighting circuit is used. The core of the coil is alternately magnetized and demagnetized. When magnetized, the core attracts the holder containing a hard alloy plate. On demagnetization, the core permits the holder to be repulsed by a spring, thus resulting in the reciprocating movement of the holder. Units similar to that shown in Figure 5 have been used at one plant, two shifts a day, for over 2 years.

An electric-spark unit for plating, hardening, and engraving was designed and manufactured by the Moscow Elektra TsNIL [Central Scientific Research Laboratory?] and was shown at the Polytechnical Museum in an exhibition devoted to high-speed methods of metalworking. This unit occupies an area of 700 to 600 millimeters and has three work conditions for plating operations with direct current ($I = 0.5$ ampere, $C = 30$ microfarads; $I = 1.0$ ampere, $C = 90$ microfarads; $I = 1.5$ amperes, $C = 180$ microfarads); voltage $U = 160$ volts. The unit contains a selenium rectifier which is the source of the direct current. Additional resistance is interlocked with the capacitor in each of the above-mentioned working conditions. The "mild" condition is used for engraving (electric pen). Instead of the gun, a very simple and convenient vibrator is used, the action of which is stopped automatically, simultaneously with the completion of the basic operation. Reamers, face- and end-milling cutters, etc., are held in centers during such processing, whereas flat objects are mounted on the table. Such compact units will be produced serially in the near future by the Soviet electrical industry.

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The following electrical conditions are used in electric-spark plating, hardening, and engraving:

Plating of a Cutting Tool With Hard Alloy

Rough process	Current I = 2-4 amperes Capacitance C = 200-300 microfarads Voltage U = 160-220 volts
Finishing process	Current I = up to 1 ampere Capacitance C = up to 100 microfarads Voltage U = up to 160 volts

In some cases before plating, to create a more durable hard surface, hardening takes place under the mild condition:

Current I = up to 0.8 ampere
Capacitance C = up to 30 microfarads
Voltage U = up to 100 volts

The types of hard alloy recommended for the plating of cutting tools are T15K6, T30K4, T60K8, VK8, etc. The thickness of plating varies between 0.02-0.1 millimeter.

Surface Hardening With Graphite

The following electric-spark parameters are to be observed:

Current I = 1-2 amperes
Capacitance C = 40-100 microfarads
Voltage U = 100 to 120 volts

The recommended types of graphite to be used are: EG-2 and EG-4. The hardened layer has a thickness of 10 microns.

Electroengraving

The electroengraving working conditions are as follows:

Current I = up to 0.5 ampere
Capacitance = up to 5 microfarads
Voltage U = up to 80 volts.

For engraving, the polarity must be changed by connecting the positive terminal to the object to be engraved and the negative terminal to the electrode tool.

Hard-alloy plating is used for the most part on cutting tools to increase their durability. Since the surface finish resulting after the plating of cutting edges leaves much to be desired (corresponding to only the fifth or sixth class of GOST 2789-45), it is recommended that this treatment be used primarily for roughing tools (such as cutters, milling cutters, reamers, drills, counter bores, broaches, forming tools, and slotting tools). In some instances, hard alloy can be used for plating working surfaces of measuring tools, in which case subsequent finishing is always necessary.

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Plating can be effected not only with hard alloys but also with other raw materials as well. For example, to salvage a defective part made of silumin which was found to contain a cavity, silumin, lead, or other material can be used to cover and fill in the defect. Such reconditioning is used extensively in plant practice. Reconditioning of reamers with 0.04 to 0.05 millimeter of hard alloy is entirely possible. The advantage of a hard alloy plated cutting tool over an ordinary hard-alloy tipped cutting tool is that the former can wi[illegible] impacts whereas the latter is very fragile and cannot endure impact loads. Therefore, planing, slotting, and boring tools are not made with hard-alloy tips, but are produced of high-speed steel or its substitutes. The same tools, plated with hard alloy, can handle impact loads, and they have a durability of 1.8 to two times that of the ordinary cutting tools.

Generally, the durability of a cutting tool plated with hard alloy by the electric-spark process, is two to three times that of an ordinary tool. In some instances the durability of friction tools (such as dies, cams for automatics, blades for centerless grinding machines, etc.) increases ten to 40 times.

Lately, the electric-spark process has found increasingly wide usage in surface hardening with graphite, a method which is employed in the processing of cutting tools. Since the surface finish thus produced is superior to the finishes resulting from hard-alloy plating, this method of hardening can be used also for measuring tools.

While hard-alloy plating is useful as applied to a limited number of tools, primarily roughing tools, an entire cutting tool can be subjected to hardening. Threading tools (such as dies, taps, chasers, etc.), gear cutters, hobs, etc., can be processed in this way.

The hardened layer is of small thickness (2-7 microns) and does not result in the enlargement of the tool in view of its diffusive nature. The hardened surface is 1.1 to 1.2 times harder than the original surface, while the durability of the cutting tool is increased 1.5 to 1.8 times.

It should be noted that the hardening operation is, in some instances, superior to plating and can be used on many mechanical parts which are subject to friction. Since plating and hardening with graphite are done under ordinary atmospheric conditions, it can be assumed that nitrogen will affect the working surface; however, the degree of its influence is negligible. Recently, even hard-alloy tools have been subjected to graphite hardening.

Engraving by the electric-spark process is remarkable because it can be performed on metals of any hardness, without being hindered by the heat treatment of the part. Engraving by the electric-spark process is performed in a simple, accurate, and clear fashion and has obvious advantages over conventional engraving. The electric-spark pen can be set up as a fountain pen, its size not exceeding that of an ordinary pocket pencil. Engraving is used in connection with machine parts, tool equipment, all types of finished products put out by plants, etc.

3. The Grinding and Finishing of Cutting Tools

The electric-spark method of metalworking is being improved constantly, and, therefore, its equipment is constantly changing. For forming apertures by the electric-spark process, drilling machines, vertical milling machines, etc., are used, because only a forward movement of the electrode tool in relation to the electrode workpiece is necessary. For plating and hardening, a vibrator to effect the reciprocating movement of the electrode tool is required. In the case of grinding and finishing, the mechanical arrangement has to undergo a slight

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modification, wherein the electrode tool has a variable-speed rotary movement. During the process, the workpiece and the electrode tool (cast iron or steel disk) must be brought together continuously, always leaving a clearance equal to the spark gap. The electrical arrangement remains unchanged (Sketch e, Figure 1). At present, the special equipment for the grinding and finishing of tools is still in the designing and experimental stage.

Figure 7 /Figure 6 is not reproduced but is available in the original in CIA/ shows a machine tool for grinding and finishing cutting tools. The bed of the machine is a solid iron casting. The upper part supports a two-speed, alternating-current motor (2). A disk tool (11) is fastened to the shaft of the motor. The shaft, which is electrically insulated from the rotor, serves to transmit the electric power from the current collector (1) to the disk tool. The lever (3) serves to vary the speed of disk (11) rotation.

The universal cutting-tool holder (13), which has 3 degrees of free movement, is secured to the tool being processed (12). The lever (10), the flywheels (6 and 7), and the control buttons (17) are used for starting and controlling the machine.

The bottom part of the bed contains the electrical accessories, consisting of the condensers (4) the mechanical rectifier (16), additional resistors (5), the tank (15), and the pump (8). The pump forces the working medium through a hose into the discharge region between the electrode disk (11) and the tool being processed (12). To prevent excessive spattering of the dielectric medium, a protective shield and a basin are used beyond the region of spark formation. The cutting tool (12) can be set at any angle in relation to the disk, corresponding to the geometrical parameters provided by the working plan.

A suitable machine tool can be converted from any tool-grinding equipment. The modification consists either in insulating the machine spindle which carries the disk tools, or in simply insulating the disk from the spindle.

Such a tool grinder was demonstrated at the Polytechnical Museum exhibition featuring high-speed metalworking methods. The electrical component was assembled in a separate panel and placed alongside the machine. The entire unit was manufactured by the Plant imeni Ordzhonikidze in accordance with the technology for electric-spark grinding of cutting tools, for which Ulitin and Zolotykh hold the certificates of authorship.

The electrical and other parameters of the electric-spark technology for grinding and finishing of hard-alloy cutting tools are as follows:

Grinding

Current I = 150-200 amperes
Capacitance C = 400-600 microfarads
Voltage U = 20-25 volts
Speed of disk rotation V = 12-15 meters per second
Liberal flow of the dielectric medium (oil, etc.)

Finishing

Current I = 1-5 amperes
Capacitance C = 1-10 microfarads
Voltage U = 15-20 volts
Speed of disk rotation V = 25-30 meters per second

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The change from grinding conditions to finishing is done smoothly. The hard-alloy tool or disk must have a reciprocating movement in a direction perpendicular to the axis of spindle rotation.

Metallographic studies of surfaces produced by the electric-spark process indicated the absence of cracks, microcracks, and other defects. The surface of the cutting edges finished by the electric-spark method measure in the 7th, 8th, and 9th class of GOST 2789-45. This corresponds to the latest technical specifications of cutting-tool manufacture. Studies of the durability of hard-alloy cutting tools, ground and finished by the electric-spark method, were conducted by Krivoukhov, Doctor of Technical Sciences, and showed good results. Their durability is no less than that of abrasively ground tools, and in plant use they are found to be about 1.5 times more durable.

Electric-spark grinding and finishing of hard-alloy cutting tools is freeing Soviet industry from using acutely scarce and expensive "extra carborundum," diamond, and diamond derivatives.

The cost of hard-alloy cutting tools, ground and finished by the electric-spark method, is 1.7 times less than that of tools processed by the abrasive method. Hard alloys do not readily absorb impact loads during grinding or while in operation, and they crumble. Cracks frequently develop in the course of abrasive grinding of hard alloys. Electric-spark grinding and finishing always take place in the spark gap between the tool being ground and the working disk. Therefore, there is no cause for cracks or nicks to develop.

Electric-spark processing of hard alloys is five to seven times more productive than the abrasive process. It makes possible the complete mechanization of labor, with resultant improvement in hygienic and sanitary working conditions.

The electric-spark process of grinding and finishing can be applied to all cutting tools made of high-speed, tool alloy and other steels. Moreover, the operating conditions of the electrical and other parameters permit their employment in the grinding and finishing not only of cutting tools, but of measuring tools as well. The quality of the surface finish (class 8, 9, and 10 of GOST 2789-45) and the absence of a defective layer serve as a basis for assuming that the specified operating conditions can be used successfully in the manufacture of hard-alloy measuring tools. This feature permits extensive interchangeability of machine and instrument parts in large-series and mass production.

New production horizons are also being opened beyond the field of grinding, cutting, and measuring tools. Low-voltage operating conditions now permit the processing of a whole series of dependable machine parts which have gone through special heat treatment for obtaining particularly hard surfaces (casehardening, cyaniding, nitriding, chrome plating, etc.)

4. Cutting

Electric-spark processing at low voltages (up to 20-25 volts) of a large number of materials with the use of special liquid working media (kaolin suspension, waterglass, various salts, etc.) can be carried out according to the electrical arrangement shown in Sketch e, Figure 1, but without the capacitor. This is especially applicable in cases where it is not necessary to obtain clean, precision-cut surfaces, as in various types of rough cutting of any metal.

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The electric-spark method can be used for cutting rails, various sizes and shapes of rolled iron, pipes, ingots of any dimension, sheet iron, etc. The process makes it unnecessary to use scarce and expensive circular saws made of special steel. The cutting operation is performed by an ordinary iron disk, on any cutting-off machine. It is only necessary to effect the above-described modification, identical with that made on the machine used for grinding operations.

The speed of cutting-disk rotation is between 12-25 meters per second. The size of the disk selected depends on its intended use; 100-500 millimeters in diameter and 0.5 to 1.0 millimeter in thickness. The workpiece is clamped in a vise mounted on the machine bed, and the disk is secured to a spindle which is insulated from the bed. Liquid dielectric medium is then fed liberally into the discharge zone where the cut is to be made.

The cost of electric-spark metalcutting is from two to three times less than that of cutting by means of circular or band saws. The cross-section cutting of a rail on a circular saw takes 5-7 minutes whereas with the electric-spark process this operation consumes 2-3 minutes.

Prospects for Further Developments in Electric-Spark Metalworking

The working of metals by means of the electric-spark process is finding increasing use in various branches of the metalworking industry. The preceding chapter dealt only with the basic methods of electric-spark treatment without mentioning other production possibilities. No mention has been made of its use in the rapidly developing field of powder metallurgy. For instance, sometimes it becomes necessary to manufacture a complex hard-alloy worm gear which cannot be made by casting, forming, or machining a solid piece of hard alloy. The parts for this worm gear can be made only by fine-powder pressing. These basic powders can be produced by the electric-spark method.

Aperture making by the electric-spark process gives a free hand to designers and technologists, allowing them to choose metals of any hardness for various parts and to make apertures of any shape (curvilinear, acute-angle, etc.) with the assurance that after heat treatment these parts will not become deflected or develop cracks at their acute angles. All of this becomes possible because the parts can be heat treated to a specified hardness prior to the final finishing of complex profiles. Up to now, production of apertures with curved axes was considered impossible, however, this limitation has been overcome by means of the electric-spark method. This technique enables designers and technologists to improve the design of complicated machines and engines and to simplify the technology of their manufacture.

It was also considered impossible to produce profile-shaped, round, and disk-shaped hard-alloy, precision cutting tools within tolerances corresponding to the first and second degrees of precision and having surface finishes corresponding to classes 7 and 8 of GOST 2789-45. Now, by electric-spark grinding and finishing, this technological problem can be solved.

It is known that in the abrasive method of grinding, the grinding wheel is in direct contact with the workpiece and exerts a certain pressure upon it. Furthermore, the removal of waste products (such as the abrasive dust and chips) is difficult, especially in face grinding. Because of friction between the grinding wheel and the workpiece, the latter becomes · y hot, and there is a danger of cracks forming upon cooling. All of this limits the efficiency of abrasive-grinding operations.

In electric-spark grinding, the gap leaves room for the removal of waste; it prevents friction, and consequently avoids the possible formation of surface defects. Therefore, by changing the operating conditions, it is possible to attain high productivity. A number of experiments conducted over a period of years shows that the productivity of electric-spark grinding is five to seven times that of abrasive grinding and in some cases, it is ten to 15 times as great. Thus, it can be assumed that in the near future, electric-spark grinding will supplant abrasive grinding at all plants.

Further development of electric-spark metalworking should proceed along these lines:

1. Development and utilization of multicircuit electrical installations to increase productivity, particularly in connection with aperture making.

2. Development of new types of units for aperture making, tool grinding, grinding, cutting, plating, hardening, etc., with maximum application of automatic features, and at the same time, maintaining simplicity of design.

3. Development of new materials for the electrode tools to insure minimum wear and maximum productivity, maintaining the specified sizes of workpieces.

4. Formulation of operating conditions (electrical and others) to obtain optimum productivity, surface finish, and dimensions of the workpiece and the electrode tool, etc.

5. Theoretical analysis of all phenomena connected with the various operating conditions, with mathematical determination of the fundamental laws governing these phenomena, on the basis of thorough and objective classification and generalization of given experiments, and with proper criticism of their study.

Extensive introduction of electric-spark metalworking at plants of the metalworking industry does not require the construction of specialized electric-spark units. First, it is necessary to utilize available plant resources and to adapt unused equipment for use in the electric-spark process.

For piercing, the use of vertical-milling machines and other machine tools is recommended. Almost all plants have idle drilling machines which can be modified very easily for aperture making, especially with hand feed (Figure 2). In the future, it will be possible to convert to automatic feed.

An ordinary fitter's workbench can be used as the base for a plating or surface-hardening unit.

Grinding machines and tool grinders also lend themselves to easy conversion. This can be accomplished simply be electrical insulation of one of the electrodes of the circuit, either the workpiece or the tool.

In locating an electric-spark shop, section, or laboratory, only a separate, well-ventilated room is necessary. Motor-generators can supply direct current (those having a power of 10-15 kilowatts and voltage of 220 volts for aperture making and plating; and those with 10-12 kilowatts and 20-30 volts for grinding, tool grinding, and cutting). A mechanical rectifier of 2-3 kilowatt power can be installed within the control panel for each unit. It is also desirable to provide space for auxiliary tools at such shops.

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The scope of work at an electric-spark shop serving one tool-making enterprise consists of plating and hardening all new cutting tools, as well as those which had been ground previously; grinding and finishing hard-alloy tools, especially those intended for high-speed cutting; producing holes in heat-treated and hardened equipment (dies, press molds, etc.); and repair and restoration operations.

It is recommended that electric-spark shops be organized at tool-making enterprises before facilities are installed for series work.

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[Appended figures follow.]

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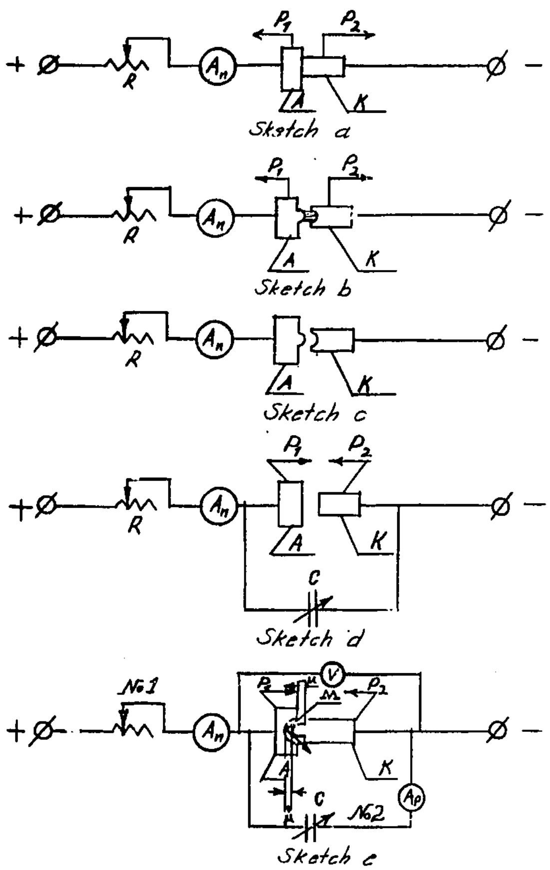

Figure 1

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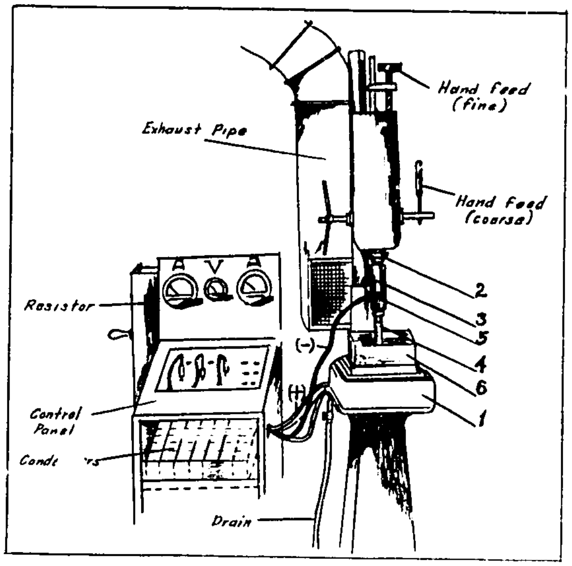

Figure 2

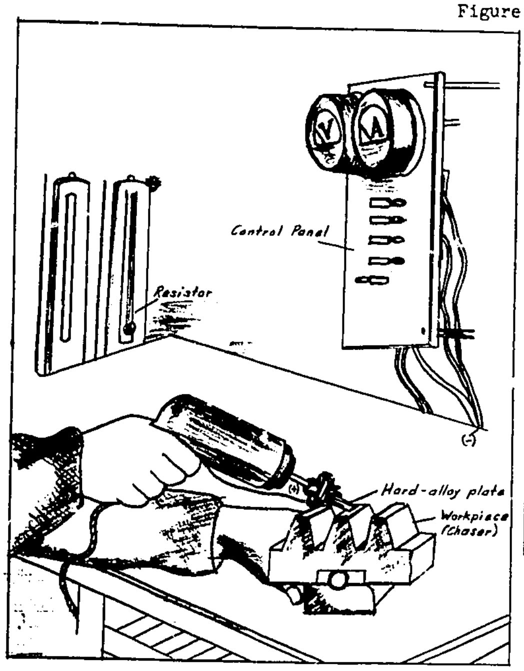

Figure 5

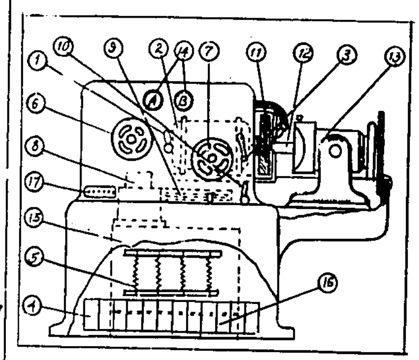

Figure 7

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